Distribution and Abundance of Butterflies in the Urbanization Zones of Porto Alegre, Brazil

Alexandre Ruszczyk

Av. Azenha N° 330 ap. 11, Porto Alegre 90.060, RS, Brasil

Abstract The distribution of butterflies in the urban area of Porto Alegre was analysed by means of transects of avenues and data collected over a grid of 111 observation points. Maps were drawn showing the urbanization zones of the city, percent of vegetation cover as well as the distribution of 29 butterfly species. Three zones with relative uniformity can be identified along the urbanization gradient: B (buildings higher than four stories), vegetation cover below 20%; HB (houses and buildings of less than four stories), vegetation cover between 20 and 40% and H (houses, also including open areas within the city), vegetation cover above 40%. The distribution of butterflies in the city showed a life zone pattern very well correlated and oriented with the urbanization gradient. The border between zones H and HB represented a barrier for several species strongly associated with woods or natural fields, representing the most important transition area in the city fauna. The increase in the urbanization and pollution was accompanied by a decrease in the number of species and individuals registered as well as by a homogenization in butterfly distribution. In terms of abundance and distribution of its individual elements, the butterfly community of Porto Alegre is consistently structured in accord with the urbanization gradient, represented as distance from the center of the city. The predominance of this parameter is probably due to the fact that this distance is the main conditioner of many variables which are important for butterflies (such as urban climate, percent vegetation cover, air pollution and human density). Species of open areas, with high vagility, nectar feeders and with larvae feeding on exotic cultivated plants are dominant in the city.

Introduction

Among the more esthetically pleasing animals which inhabit urban ecosystems along with man, birds and butterflies have high ranking. Few authors have attempted to investigate the determinants of butterfly occurrence and non-occurrence in man-made environments; most publications about butterflies in urban areas simply report a list of species found in a given city. In a more in-depth study, Shapiro & Shapiro (1973) studied the Staten Island (USA) butterfly community and called attention to its homogeneity. The butterflies found in abandoned lots, always the same, were increasing in number and distribution while the native and specialized forms were declining. The first group included vagile colonizers with a high reproductive rate, feeding on weeds and probably tolerant of air pollution. Yamamoto (1977) studied the butterflies of Sapporo (Japan) and found that most of the individuals belonged to a small number of species; a decline in the butterfly fauna paralleled the increase of urbanization. Species of open areas, which hibernate during the pupal stage and reproduce three or more generations per year, were those more resistant to urbanization. His results showed the substitution of forest species by open area species. Singer & Gilbert (1978) offered some general theoretical considerations about butterfly ecology in urban environments.

In this work the entire urban area of Porto Alegre (Rio Grande do Sul, Brazil) was sampled for butterflies. The main objectives were to investigate butterfly distribution over the urbanization gradient and the influence of habitat variables on butterfly abundance.

Study Area

The city of Porto Alegre is located in southern Brazil (30°02′ S, 51°14′ W), with a population of over a million inhabitants. The altitude varies from 4 to 300 m above sea level (mean about 80–100 m). The region has a temperate-subtropical climate with high humidity and moderately high temperatures in the summer. The annual mean temperature is 13.8°C and the average rainfall 1322 mm.

The city is surrounded by agrarian ecosystems to the north, south and east; to the west are found the aquatic ecosystems of Guaiba River (Figure 1a). Within the city are found only remnants of woods in hard-to-reach places in the southern sector, where urbanization has been partially stopped. A field vegetation, either managed or abandoned, presently predominates on the periphery of the city.

Over a 1:20.000 city map was laid a 5-cm grid (equal to 1 km^2 real size). Using the geometric center of each square, 111 circles 3 cm in diameter (300 m radius or 0.283 km^2 real size) were defined. The circles corresponded to sampling subunits called observation points (OP). The distance of each OP from OP E_5 (Figure 2) in the center of the tall building zone was considered "distance from the center of the city". The mean altitude of each OP was estimated as the arithmetic mean between its highest and lowest points. Over a 1:8.000 photograph of each OP was laid a 6 × 6 cm square of millimetered paper (0.2304 km^2 actual area). The parts covered by plants, including native vegetation as well as lawns, back yards, vacant lots and street trees, were shaded. The calculated percentage of vegetation cover of each OP was extrapolated to the area of 1 km^2 (Figure 1b).

By examination of 1:20.000 aerial photographs of the city with the aid of a stereoscope, three zones of different intensities of urbanization could be drawn over a political map at the same scale: high (buildings zone or zone B; vegetation cover below 20%; zero to 2 km distant from the center of the city), medium (houses and buildings zone or zone HB; vegetation cover between 20 and 40%; 2 to 7 km distant from the center of the city) and low (houses zone or zone H; vegetation cover above 40%; 4 to 12 km distant from the center of the city). The borders of the zones were adjusted by examination *in loco*. The final map (Figure 1c) was simplified to polygons, by drawing tangential lines to the borders of the different zones of urbanization (Figure 1d).

The radial arrangement of the main avenues of Porto Alegre has determined an urbanization gradient also radial and relatively similar in all directions from the center of the city. Over the urbanization gradient is found a complementary gradient of vegetation covering, also with a radial aspect and similar preferential orientation (northeast-southeast) (Figure 1b).

Zone B and industrial and shopping areas generally show less than 20% plant cover. Zone HB has under 40% plant cover, showing a close spatial relationship with the 15−30% class in Figure 1b. Zone H has in general plant cover value over 40%, reaching a maximum of 78%. The mean value was 39.3% (s = 17.2). The minimum value for this variable was 7.2% in OP E_4.

Methods

The distribution of butterflies was investigated using two methods: transects, and data recording in observation points.

Transects

Four transect routes were used (AB, CD, EF and GH), along the main avenues out from the center of the city. The censuses began at 10 a.m. at the inner end of each route, and consisted of a round trip to the outer end and back. Ten such censuses were done along each route. All butterflies seen by naked eye were registered, whether flying or sitting up to 10 meters back from the street side of the buildings. The location of each individual was determined in relation to the nearest cross street.

Data Recording in Observation Points

The whole set of the OPs was explored during three sampling periods (November-December 1980, March-April 1981 and June-July 1981). In each of these periods the OPs were visited sequentially, five per day. First the OPs of row 7 were visited followed by rows 8, 6, 9, 5 and thus successively (Figure 2). In each OP, a 45-minute period was spent constantly walking the streets and recording the number of individuals of different butterfly species seen. The field data were transferred to computer cards and all calculated values were obtained through the use of SPSS (Nie et al., 1975) programs.

Results and Discussion

Distribution of Butterflies along the Transect Routes

Table 1 includes the total number of individuals of different species along the four transect routes. The recordings for the final 1.6 kilometers of route AB (8 km in total length) are not included in this table, since they represent extra-urban data, not comparable to those obtained for other routes. Figures 3, 4, 5 and 6 show graphic representations of the butterfly groups along the four routes.

From AB to GH there occurs a levelling of topography, an increase of urbanization intensity and a decrease in the number of individuals recorded per km of transect (Table 1).

Dryas iulia, *Ascia monuste orseis* and *Phoebis philea* were the most numerous butterflies, totalling 30% of the recorded insects along each route. The predominance of these species is due, among other factors, to their great abundance in the region (including within the city), speed and mobility, and the vivid colors of their wings which allows easy spotting.

Table 1. Butterflies observed along 20 transect (center-suburbs-center) on four acess routes. Explanation in the text.

SPECIES	ROUTE AB (17.3)*		CD (14.7)		EF (11.9)		GH (10.5)		TOTAL	
	N	%	N	%	N	%	N	%	N	%
Dryas iulia (Fabricius, 1775)	88	17.0	63	14.3	46	12.9	26	9.9	223	14.1
Ascia monuste orseis (Latreille, 1819)	65	12.5	55	12.4	49	13.8	32	12.2	201	12.7
Phoebis philea (Johansson, 1763)	44	8.5	45	10.2	47	13.2	21	8.0	157	9.9
Anartia amathea (Eschscholtz, 1821)	23	4.4	24	5.4	22	6.2	49	18.7	118	7.5
Papilio scamander Boisduval, 1836	22	4.2	27	6.1	25	7.0	15	5.7	89	5.6
Phoebis spp.	21	4.0	22	5.0	23	6.5	17	6.5	83	5.3
Junonia evarete (Cramer, 1779)	25	4.8	19	4.3	16	4.5	21	8.0	81	5.1
Colias lesbia pyrrhothea (Hübner, 1823)	29	5.6	34	7.7	1	0.3	–	–	64	4.1
Tatochila autodice (Huebner, 1818)	30	5.8	14	3.2	9	2.5	1	0.4	54	3.4
Papilio anchisiades capys Huebner, 1809	30	5.8	15	3.4	8	2.2	–	–	53	3.4
Urbanus spp.	16	3.1	13	2.9	13	3.6	8	3.1	50	3.2
Actinote spp.	6	1.2	18	4.1	7	2.0	13	5.0	44	2.8
Euptychia spp.	6	1.2	4	0.9	14	3.9	16	6.1	40	2.5
Anosia gilippus (Cramer, 1775)	22	4.2	6	1.4	8	2.2	2	0.8	38	2.4
Agraulis vanillae maculosa (Stichel, 1907)	3	0.6	8	1.8	13	3.6	8	3.1	32	2.0
Eurema spp.	9	1.7	6	1.4	10	2.8	1	0.4	26	1.6
Phyciodes spp.	2	0.4	5	1.1	9	2.5	8	3.1	23	1.5
Battus polydamas (Linnaeus, 1758)	12	2.3	3	0.7	2	0.6	–	–	17	1.1
Eunica margarita (Godart, 1822)	9	1.7	5	1.1	1	0.3	2	0.8	17	1.1
Dione juno (Cramer, 1779)	2	0.4	8	1.8	4	1.1	–	–	14	0.9
Methona themisto Huebner, 1818	8	1.5	3	0.7	1	0.3	1	0.4	13	0.8
Papilio hectorides Esper, 1794	3	0.6	5	1.1	2	0.6	–	–	10	0.6
Biblis hyperia (Cramer, 1779)	3	0.6	–	–	4	1.1	2	0.8	9	0.6
Papilio thoas brasiliensis Rothschild & Jordan, 1906	5	1.0	2	0.5	–	–	1	0.4	8	0.5
Placidula euryanassa (Felder, 1860)	–	–	4	0.9	1	0.3	3	1.1	8	0.5
Adelpha spp.	–	–	4	0.9	3	0.8	1	0.4	8	0.5
Heliconius erato phyllis (Fabricius, 1775)	2	0.4	3	0.7	1	0.3	1	0.4	7	0.4
Dryadula phaetusa (Linnaeus, 1758)	1	0.2	–	–	2	0.6	4	1.5	7	0.4
Siproeta stelenes (Linnaeus, 1758)	1	0.2	1	0.2	3	0.8	1	0.4	6	0.4
Papilio astyalus Latreille, 1819	4	0.8	1	0.2	–	–	–	–	5	0.3
Diaethria spp.	1	0.2	3	0.7	1	0.3	–	–	5	0.3
Doxocopa laurentia (Godart, 1821)	3	0.6	1	0.2	–	–	–	–	4	0.3
Hamadryas amphinome (Fruhstorfer, 1916)	2	0.4	2	0.5	–	–	–	–	4	0.3
Anaea itys (Gmelin, 1791)	1	0.2	1	0.2	1	0.3	1	0.4	4	0.3
Dismorphia spp.	2	0.4	–	–	2	0.6	–	–	4	0.3
Hamadryas spp.	2	0.4	1	0.2	–	–	–	–	3	0.2
Epiphile huebneri Hewitson, 1861	–	–	1	0.2	2	0.6	–	–	3	0.2
Heliopetes omrina (Butler, 1870)	–	–	–	–	1	0.3	2	0.8	3	0.2
Eurema deva deva (Doubleday, 1847)	1	0.2	1	0.2	–	–	1	0.4	3	0.2
Opsiphanes invirae Stichel, 1901	1	0.2	2	0.5	–	–	–	–	3	0.2
Dynamine myrrhina (Doubleday, 1849)	1	0.2	–	–	–	–	1	0.4	2	0.1
Riodina lysistrata (Berg, 1896)	–	–	1	0.2	–	–	1	0.4	2	0.1
Praepedaliodes phanias (Hewitson, 1861)	1	0.2	–	–	1	0.3	–	–	2	0.1
Mechanitis lysimnia (Fabricius, 1793)	2	0.4	–	–	–	–	–	–	2	0.1
Euryades corethrus (Boisduval, 1836)	1	0.2	–	–	–	–	–	–	1	0.1
Pyrgus oileus (Stoll, 1790)	1	0.2	–	–	–	–	–	–	1	0.1
Pyrgus communis (Giacomelli, 1928)	–	–	–	–	–	–	1	0.4	1	0.1
Doxocopa kallina (Staudinger, 1886)	1	0.2	–	–	–	–	–	–	1	0.1
Vanessa braziliensis (Moore, 1883)	1	0.2	–	–	–	–	–	–	1	0.1
Marpesia petreus (Cramer, 1776)	–	–	1	0.2	–	–	–	–	1	0.1
Eypanartia bella (Fabricius, 1793)	–	–	–	–	1	0.3	–	–	1	0.1
Philoros rubriceps opaca (Boisduval, 1870)	–	–	–	–	–	–	1	0.4	1	0.1
Others	7	1.3	11	2.5	3	0.8	–	–	21	1.3
Total	519	100.0	442	100.0	356	100.0	262	100.0	1579	100.0

* (N/Km/TRANSECT)

The papilionids (Figure 3) show a reduction in the number of individuals from AB to GH; in the latter transect, except for one individual of *Papilio thoas brasiliensis*, all those recorded belonged to the species *P. scamander scamander*. This monotony is in accord with the small number of species of this family observed in the OPs located in this area of the city.

The sap and fruit eating nymphalids were most common along AB, also decreasing in the direction of GH (Figure 6). All these species are native of subtropical woods on the city periphery, showing their greatest numbers on the distal end of AB, which crosses areas with remnants of this habitat.

Along the routes AB, CD and EF the different families and subfamilies showed a sharp reduction of the species number and individuals inside the limits of zone B; only one or two species were recorded for each group of butterflies. On GH, however, there was a greater homogeneity in the distribution of these groups, represented all along the route by the species that on other routes were well represented in zone B. This emphasizes the environmental stress of this region. The homogeneity in the distribution of the different groups of butterflies along GH is probably due in part to the spatial uniformity of this portion of the city. This area has a very regular disposition of streets, similar to a chessboard, and is extremely flat with elevations below 5 meters, which represents a low diversification of habitats. In aerial photographs it shows great similarity among its different sites. The scarcity of vegetation on the margins of route GH tends also to increase the homogeneity in the distribution of butterflies, since it eliminates a factor of concentration of these insects. Farrapos Avenue, the greatest part of route GH, is surely the avenue with the greatest air pollution in the city due to particles and industrial gases as well as from vehicles. Pollution is a factor of homogenization of environmental conditions consequently decreasing the complexity of animal and plant communities belonging to a certain biotope. Thus, the smaller species number and homogeneity of distribution found along GH may also be explained by the air pollution in this area.

The Urban Community of Butterflies

The data in Table 2 show the large number of individuals of a small number of butterfly species in the urban area. The data provide evidence that the butterfly communities of Porto Alegre are organized with a consistent structure. This can be seen from the results of the two methods used. For example, the more abundant species in the transects and OPs hold the top positions in the abundance ranking in the majority of routes and regions of the city (Tables 1 and 2). The majority of the genera and species which represent less than 2% of the records in the transects maintain this low proportion also in the OPs. It will be

Table 2. Total number of butterflies observed in 11 regions of the city of Porto Alegre.

SPECIES	REGIONS I	II	III	IV	V	VI	VII	VIII	IX	X	XI	EN	%
Ascia monuste orseis (Latreille, 1819)	117	100	111	138	102	80	90	80	58	70	65	1011	8.71
Dryas iulia (Fabricius, 1775)	152	145	96	154	120	56	109	62	37	26	17	974	8.39
Junonia evarete (Cramer, 1779)	44	46	122	62	83	70	99	64	110	44	48	792	6.82
Urbanus spp.	49	116	117	69	74	64	80	61	59	33	30	752	6.48
Tatochila autodice (Huebner, 1818)	63	84	55	57	74	55	47	43	45	39	30	592	5.10
Phoebis philea (Johansson, 1763)	76	86	60	57	43	29	67	62	12	43	22	557	4.80
Papilio scamander Boisduval, 1836	23	48	94	13	34	29	62	51	72	53	41	520	4.48
Papilio anchisiades capys Huebner, 1809	66	73	84	48	64	23	39	30	37	26	15	505	4.35
Actinote spp.	45	67	93	28	70	16	69	25	7	12	2	434	3.74
Agraulis vanillae maculesa (Stichel, 1907)	47	67	54	47	59	59	21	34	11	17	6	422	3.63
Anosia gilippus (Cramer, 1775)	21	34	46	45	30	23	44	62	40	49	11	405	3.49
Phoebis spp.	62	61	51	37	38	27	37	40	12	14	7	386	3.32
Eurema spp.	29	36	45	36	38	35	24	41	21	5	1	311	2.68
Battus polydamas (Linnaeus, 1758)	42	26	48	50	41	19	36	16	12	8	1	299	2.58
Euptychia spp.	64	31	28	15	25	27	22	17	19	8	2	258	2.22
Anartia amathea (Eschscholtz, 1821)	24	21	33	10	7	46	13	56	11	15	12	248	2.14
Fapilio astyalus Latreille, 1819	17	22	31	33	22	10	15	12	25	7	2	196	1.69
Heliopetes omrina (Butler, 1870)	18	21	21	12	19	30	17	28	11	3	4	184	1.58
Leptotes cassius (Cramer, 1775)	19	24	20	36	19	3	25	9	10	10	6	181	1.56
Papilio thoas brasiliensis Rothschild & Jordan, 1906	15	18	15	13	18	12	22	13	15	13	10	164	1.41
Methona themisto Huebner, 1818	26	16	11	14	13	5	10	16	19	18	8	156	1.34
Vanessa braziliensis (Moore, 1883)	7	5	49	6	12	20	17	12	7	16	3	154	1.33
Phyciodes claudina (Eschscholtz, 1821)	24	18	24	19	28	5	7	3	3	6	2	139	1.20
Euryades corethrus (Boisduval, 1836)	19	8	50	17	12	21	6	4	–	1	–	138	1.19
Papilio hectorides Esper, 1794	5	7	25	9	26	24	17	13	1	3	–	130	1.12
Heliopetes alana (Reakirt, 1868)	12	10	25	15	23	14	8	12	1	1	5	126	1.09
Eurema deva (Doubleday, 1847)	8	12	12	11	12	28	9	16	5	6	–	119	1.02
Dione juno (Cramer, 1779)	12	10	7	11	14	6	16	7	9	10	2	104	0.90
Pyrgus oileus (Stoll, 1780)	8	13	13	12	20	17	5	1	6	3	5	103	0.89
Eunica margarita (Godart, 1822)	29	9	9	10	5	7	8	4	1	6	5	93	0.80
Heliconius erato phyllis (Fabricius, 1775)	33	4	4	12	15	2	10	1	3	1	1	86	0.74
Parides perrhebus (Boisduval, 1836)	19	6	4	4	13	4	9	3	2	–	2	66	0.57
Pyrgus communis (Giacomelli, 1928)	2	8	12	9	14	7	1	7	2	–	1	63	0.54
Colias lesbia pyrrhothea (Hubner, 1823)	1	2	3	4	1	5	–	3	38	–	4	61	0.53
Euptoieta hortensia (Blanchard, 1852)	3	7	21	2	8	3	5	5	1	1	–	56	0.48
Hamadryas spp.	18	6	1	6	10	2	2	2	–	1	3	51	0.44
Dryadula phaetusa (Linnaeus, 1758)	4	18	6	1	–	9	3	1	–	2	1	45	0.39
Placidula euryanassa (Felder, 1860)	6	8	3	9	9	1	4	1	–	–	1	42	0.36
Dynamine myrrhina (Doubleday, 1849)	10	4	2	3	3	–	2	2	2	1	–	29	0.25
Anaea itys (Gmelin, 1791)	3	5	8	1	1	–	5	1	–	–	2	26	0.22
Parides agavus (Drury, 1782)	21	–	–	–	3	–	–	–	–	–	–	24	0.21
Adelpha spp.	9	4	1	1	1	3	–	2	–	–	–	21	0.18
**Philoros rubriceps opaca* (Boisduval, 1870)	1	2	3	4	3	1	3	2	–	1	1	21	0.18
Biblis hyperia (Cramer, 1779)	9	1	3	1	–	2	1	2	–	1	–	20	0.17
Eurytides lysithous (Huebner, 1821)	6	3	1	4	4	1	1	–	–	–	–	20	0.17
Praepedaliodes phanias (Hewitson, 1861)	6	6	1	1	2	–	–	2	1	–	–	19	0.16
Diaethria spp.	7	2	2	1	–	2	–	1	–	–	1	16	0.14
Phyciodes ithra (Kirby, 1900)	3	2	1	1	1	–	2	3	1	–	1	15	0.13
Riodina spp.	2	1	–	3	1	2	3	1	–	–	1	14	0.12
Dismorphia spp.	4	1	3	2	2	–	–	1	–	–	1	14	0.12
Doxocopa laurentia (Godart, 1821)	3	4	–	2	–	1	–	1	–	–	–	11	0.09
Battus polystictus (Butler, 1874)	10	–	–	–	1	–	–	–	–	–	–	11	0.09
Siproeta stelenes (Linnaeus, 1758)	2	2	1	–	3	–	–	2	–	–	–	10	0.09
**Josia angulosa* (Walker, 1854)	7	–	–	1	1	–	–	–	–	–	–	9	0.08
Hypanartia bella (Fabricius, 1793)	–	2	–	–	2	1	1	1	1	–	–	8	0.07
Hamadryas amphinome (Fruhstorfer, 1916)	2	–	2	1	–	1	–	1	–	–	–	7	0.06
Doxocopa kallina (Staudinger, 1886)	2	1	2	–	–	1	1	–	–	–	–	7	0.06
Opsiphanes invirae Stichel, 1901	–	1	–	–	–	–	1	–	3	1	–	6	0.05
Parides anchises nephalion (Godart, 1819)	1	–	–	1	3	–	–	–	1	–	–	6	0.05
**Phaloe cruenta* (Huebner, 1823)	5	–	–	–	–	1	–	–	–	–	–	6	0.05
**Utetheisa ornatrix* (Linnaeus, 1758)	–	–	–	–	3	1	1	–	–	–	–	5	0.04
Prittwitzia hymenaea (Prittwitz, 1865)	2	–	–	–	–	–	–	–	–	2	–	4	0.03
Phyciodes lansdorfi (Latreille, 1820)	–	–	–	–	–	–	1	1	1	–	1	4	0.03
Siproeta trayja (Hübner, 1823)	1	1	–	–	1	–	1	–	–	–	–	4	0.03
Marpesia petreus (Cramer, 1776)	1	–	–	1	–	–	1	–	–	–	–	3	0.03
Morpho catenarius Perry, 1811	3	–	–	–	–	–	–	–	–	–	–	3	0.03
Anartia jatrophae (Johansson, 1763)	–	–	–	1	–	1	–	–	–	–	–	2	0.02
Philaethria wernicket (Röber, 1906)	2	–	–	–	–	–	–	–	–	–	–	2	0.02
**Macrocneme chrysitis* (Guerin, 1843)	–	–	1	–	1	–	–	–	–	–	–	2	0.02
Epiphile huebneri Hewitson, 1861	1	1	–	–	–	–	–	–	–	–	–	2	0.02
Others	40	33	34	38	40	39	29	30	35	7	11	336	2.89
Total	1392	1369	1568	1198	1291	950	1128	970	767	583	394	11610	100.00

* moths

shown below that this consistent organization may also be applied to the distribution of the members of this fauna.

Figures 7–10 show the distribution of the different groups of butterflies in the urban zones. These maps may be seen as an estimate of the distribution areas of different species in the urban area of Porto Alegre for the period of 1980–81; this is certainly suffering gradual modifications, considering the velocity of vertical and horizontal urbanization.

Within each subfamily or genus of butterflies there are species spread out over all zones of urbanization and others found in semi-circular bands progressively narrower and farther from the zones B and HB having as virtual center zone B. This fact is related to the radial character of the urbanization gradient and vegetation covering of the city. The majority of the species show a continuous distribution over the city, decreasing in amplitude towards more intensively urbanized zones. This, along with the high degree of vagility of the dominant species (and the majority of others) discourages the use of the expression *mosaic distribution* (often applied to soil insects) for the butterfly fauna of Porto Alegre. The expression *life zones* introduced by Merriam (1894) to designate the changes of plant communities due to altitude and latitude better characterizes the zonation of the butterfly distribution on the urban gradient.

Each species shows a more or less similar distribution pattern in the three samples, though some members of the subfamily Nymphalinae reveal seasonal variations in their distribution. In each case the pattern of distribution verified in the transect routes was in general similar to the one found for the OPs. The species that showed a rather wide distribution in the OPs (such as *P. scamander, A. m. orseis* and *D. iulia*) also showed a wide distribution along the routes of transects. The species with a more restricted distribution in the OPs such as *P. a. astyalus, P. hectorides* and *H. e. phyllis* were found to be more frequent on the outer portions of the routes. The species observed only on the border of urban area (*B. polystictus, P. a. nephalion* and *P. agavus*), within areas not reached by the majority of the routes were very infrequent along the transects. Neverthless, they were found on the distal end of route AB which reaches the city periphery. These facts emphasize the zonation of distribution areas of butterflies in the urban area of Porto Alegre.

The species that were rare in the urban area (less than 1%) in general are stenotopic in the sense of the adult being typical of field or woods. They feed in the larval stage on native plants which are infrequent or non-existent in the city. Their distribution was restricted to peripheral portions of zone H, especially in the southern sector which is richer in remnants of subtropical woods and is nearer the granitic hills of the city periphery, where still denser woods are located. In the adult stage fruit and sap feeding is predominant.

In the central areas of the city, species of open areas predominate, in accord with the results of Yamamoto (1977) on the butterflies of Sapporo (northern Japan). Species typical of natural fields behaved in Porto Alegre much like the woods species, even though they were more numerous; their distribution was concentrated in zone H.

The drying and warming of the urban environment makes the habitats of green areas similar to the xerothermic ones (Schweiger, 1953; Trojan, 1981) favoring species which tolerate low humidity and sublight (Kouch & Sollmann, 1977; Pisarski & Czechowski, 1978). Many forest species show a preference for rather low temperatures, high humidity and shade. On the contrary the field species prefer high temperatures, low humidity and sunlight (Tischler, 1965). Naturally, the ecology of a butterfly species in the city and its success in adapting to this new environment are directly related to its ecology in natural conditions. Thus the lepidopteran species typical of fields would be better pre-adapted to urban life than forest species.

If cities are considered as well illuminated open areas, warm and with low humidity, it would be reasonable that field species would be dominant in central areas of Porto Alegre; instead, they are lacking there, since natural fields are not present. The predominant physiognomy of urban habitat is closer to a savanna, with open areas where a low vegetation can grow (in general subjected to some form of management), consisting of shrubs and trees interspersed by built-up areas. From this fundamental character of the urban habitat probably comes the predominance in urban Porto Alegre of species that are not typical either of fields or woods but prefer open areas. They are eurytopic in the sense that the adults may be observed either in grasslands or in woods or mixed areas. In the larval stage they utilize native and exotic plants widely spread over the town. The available adult and larval food apparently is the main biotic ecological factor that explain the great abundance of the dominant butterflies in the urban area of Porto Alegre (Ruszczyk, 1986). Typical of these species is their degree of vagility, which certainly has contributed to their wide distribution in the city.

The Abundance of Butterflies in the Urbanization Zones

Figure 11 shows the number of butterflies recorded in the three samples of the urban area of Porto Alegre. All samples reveal a progressive reduction of the number of individuals in the direction of zone B. The mean number found for zone B was about 40 individuals, compared with about 64 in zone HB and about 130 in zone H. There is thus an increase of 60% from zone H to zone HB and more than 100% going from zone HB to H. This last increase already appeared in the OPs of zone HB located on the border of zone H (Figure 11d). The border between zone H and zone HB acts as a barrier for several butterfly species, especially those characteristic of field and wood environments. This border is the main transition area of the butterfly fauna in going out from the central area of the city. Its presence was obvious on the maps showing the number of individuals sampled in summer, winter and total seen as well as on diversity maps (in prep.). This border is also important for some bird species that are sensitive to urbanization (Ruszczyk *et al.*, 1987).

The relative influence of the variable plant cover, distance from the city center and mean altitude of the OPs was analyzed for the total number of butterflies recorded, through simple correlation and multiple regression methods. The three variables showed positive correlations with the total number of butterflies, with the respective coefficients being 0.714, 0.710 and 0.456 (all significant to the 1% level). Standardization of variables gave a standard regression coefficient of 0.326 for plant cover, 0.433 for distance from the city center and 0.154 for mean altitude, all significant to the 1% level. This indicates that the distance from the city center has a greater influence on the number of individuals than the plant cover or mean altitude. These three variables together were responsible for 61% of the explained variance of the total number of recorded butterflies for each OP. Decomposing this proportion shows the contribution of each variable:

Proportion of variance explained by all three variables	Increment due to the distance from the center of the city (ln km)	Increment due to plant cover (arc sine $\sqrt{\%}$)	Increment due to average altitude (m)	Not attributed to either X_1, X_2 or X_3 alone
(R^2)	(X_1)	(X_2)	(X_3)	
0.610	= 0.092	+ 0.041	+0.017	+0.460

Three quarters of the explained variance in the recorded number of butterflies is due to secondary effects between variables. The predominance of the single variable distance over plant cover and altitude is probably related to the large number of other variables which are directly related to it and are important to the butterflies. Variables such as temperature of the urban area, percent plant cover, degree of habitat disturbance (movement of vehicles and human beings), human population density, air pollution and intensity of urbanization are all organized as predominantly radial gradients due to the fundamental radial character of Porto Alegre's urbanization. In this way the intensity of action of these and other variables (which may be called all together *anthropogenic pressure* (Trojan, 1981)) on the lepidopterans depends in great portion on their position relative to the center of the city. This suggests a predominance of effects of physical factors on the distribution of these insects in urban areas (but see Ruszczyk, 1986 for a discussion of biotic factors in one common species, *Papilio scamander*).

Acknowledgments. I wish to acknowledge with thanks the financial support provided by Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPq). I would like to thank Aldo Mellender de Araujo, Keith S. Brown, Jr and Miriam Becker for helpful criticisms and suggestions. Celso Paulo Jaeger kindly prepared the first English version of the paper.

Literature Cited

KOUCH, K. & A. SOLLMANN, 1977. Durch Umwelteinflüsse bedingte Veränderungen der Käferfauna eines Waldgebietes in Meerbusch bei Düsseldorf. Decheniana, 20: 36–74.

MERRIAM, C. H., 1894. Laws of temperature control of the geographic distribution of terrestrial animals and plants. Nat. Geogr. Mag., 6: 229–230.

NIE, N. H., HULL, C. H., JENKINS, J. G., STEINBRENNER, K. & D. H. BENT, 1975. Statistical Package for the Social Sciences. McGraw-Hill, USA.

PISARSKI, B. & W. CZECHOWSKI, 1978. Influence de la pression urbaine sur la myrmécofaune. Memorab. zool., 29: 109–128.

RUSZCZYK, A., 1986. Mortality of *Papilio scamander scamander* (Lepidoptera: Papilionidae) pupae in four districts of Porto Alegre (S. Brazil) and the causes of superabundance of some butterflies in urban areas. Revta. bras. Biol. 46(3): 567–579.

RUSZCZYK, A., RODRIGUES, J. J. S., ROBERTS, T. M. T., BENDATI, M. M. A., MELO, M. T. Q., MARQUES, J. C. V. & R. S. DEL PINO, 1987. Distribution patterns of eight bird species in the urbanization gradient of Porto Alegre, Brazil. Cienc. Cult. 39(1) (in press)

SCHWEIGER, H., 1953. Versuch einer zoogeographischen Gliederung der rezeten Fauna der Wiener Stadgebietes. Öst. zool. Z., 4 (4/5): 556–586.

SHAPIRO, A. M. & A. R. SHAPIRO, 1973. The ecological associations of the butterflies of Staten Island. J. Res. Lepid., 12(2): 65–128.

SINGER, M. C. & L. E. GILBERT, 1978. Ecology of butterflies in the urbs and suburbs. In: FRANKIE, G. W. & C. S. KOEHLER, eds. *Perspectives in Urban Entomology*. New York, Academic. Press, p. 1–12.

TISCHLER, W., 1965. Agrarökologie. Jena, G. Fischer.

TROJAN, P., 1981. Urbanfauna: faunistic, zoogeographical and ecological problems. Memorab. zool., 34: 3–12.

YAMAMOTO, M., 1977. A comparison of butterflies assemblages in and near Sapporo city, northern Japan. J. Fac. Sci. Hokkaido Univ. Serie 6, Zoology, 20(4): 621–646.

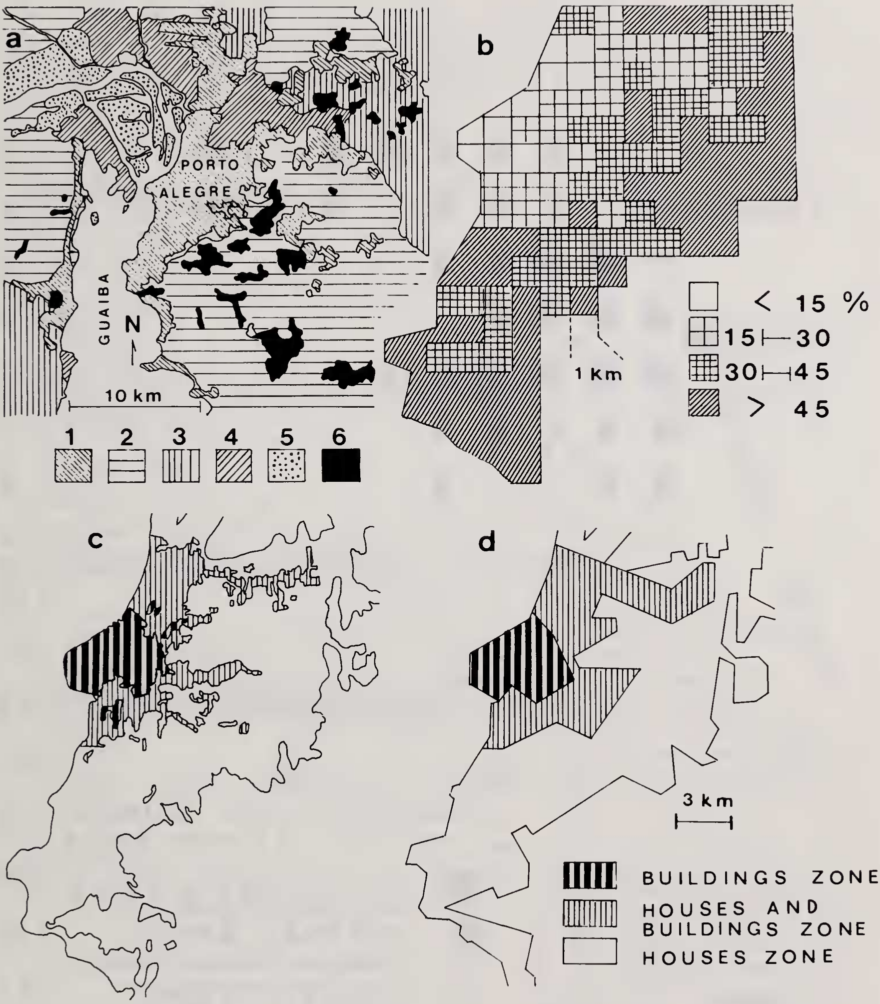


Figure 1. a) Schematic map of ecosystems within and around the city of Porto Alegre.
1. urban area; 2. agriculture; 3. agriculture and livestock; 4. agriculture and second growth; 5. marshes; 6. subtropical forest.
b) Map of percent plant cover of PA.
c) Map of urbanization zones of the city (1978).
d) Simplification of map "c".

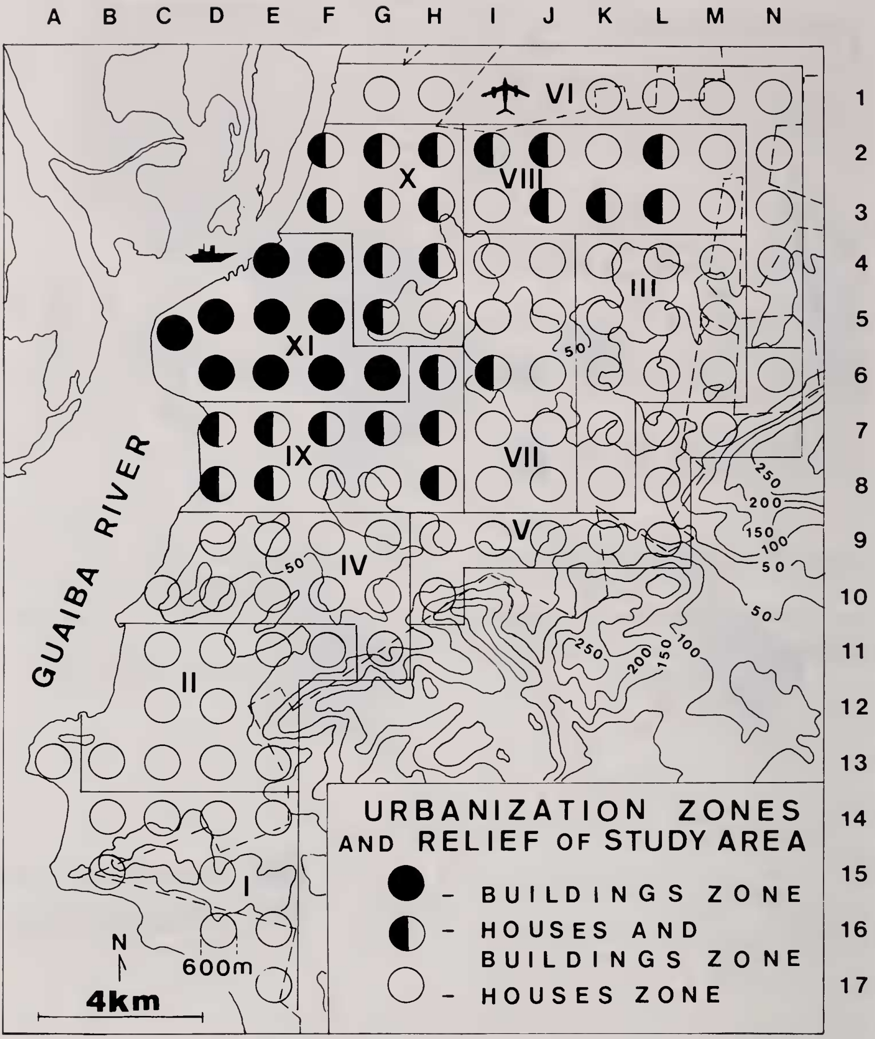


Figure 2. Location of the 111 observation points of the butterfly fauna of the city of Porto Alegre. Each observation point has a diameter of 600 m and its area was sampled three times for butterflies. The dashed line corresponds to the simplified limit of the urban area. Solid lines demarcate 11 regions into which the observation points were grouped for analysis.

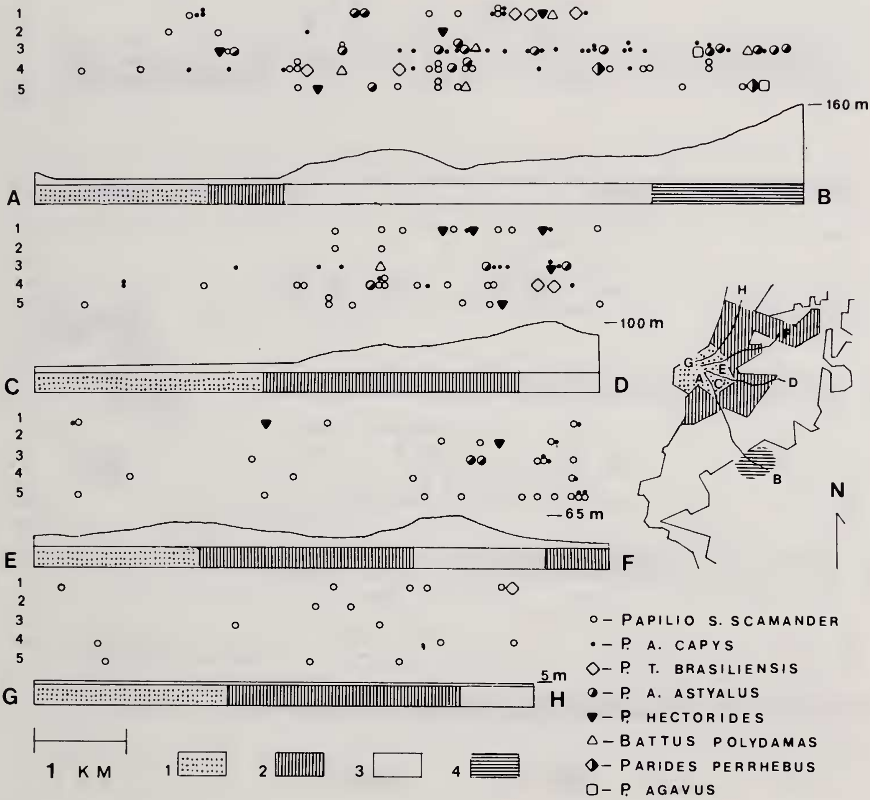


Figure 3. Family Papilionidae — Distribution in the urbanization zones of Porto Alegre. Five transects center-periphery-center (1, 2, 3, 4, 5) were made on each route in April and May 1980, February, April and May 1981, respectively. The line under the symbols is the topographic profile of the routes. The urbanization zones crossed by the routes (see map at lower right) are indicated under the topographic profile.
1. buildings zone; 2. houses and buildings zone; 3. houses zone; 4. houses zone with remnants of subtropical forest.

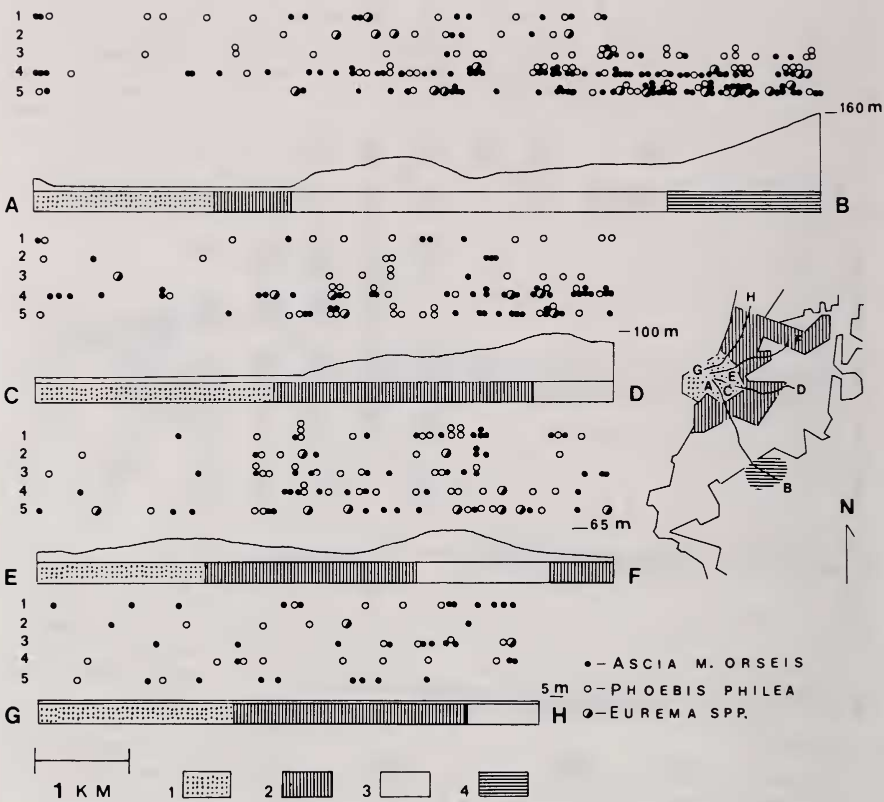


Figure 4. Family Pieridae — Distribution in the urbanization zones of Porto Alegre. See legend of Figure 3.

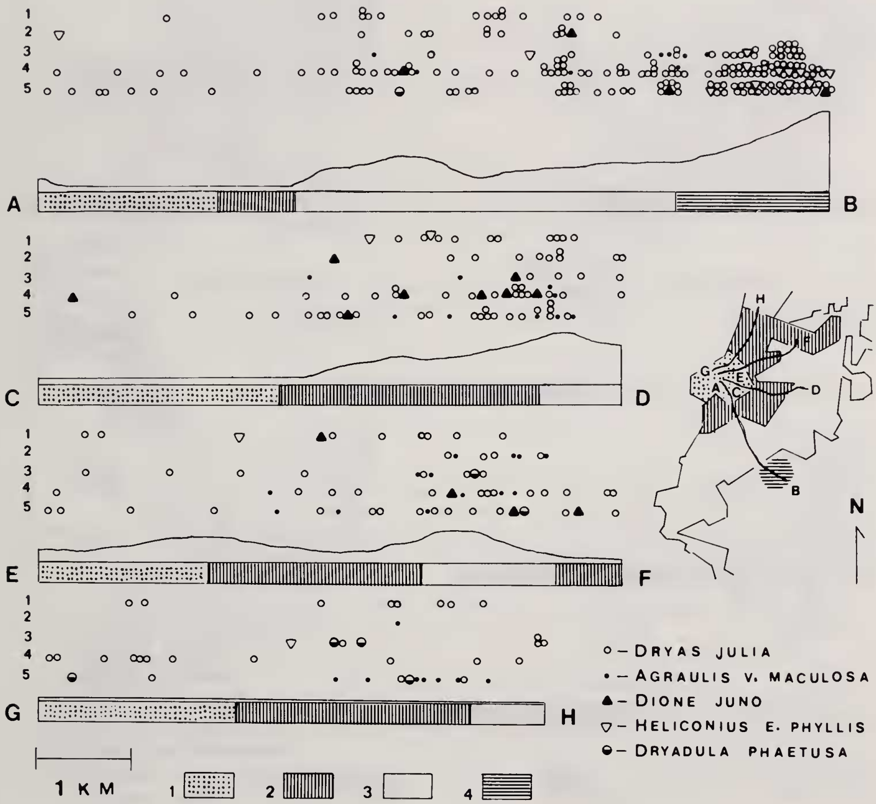


Figure 5. Family Nymphalidae (Heliconiini) — Distribution in the urbanization zones of Porto Alegre. See legend of Figure 3.

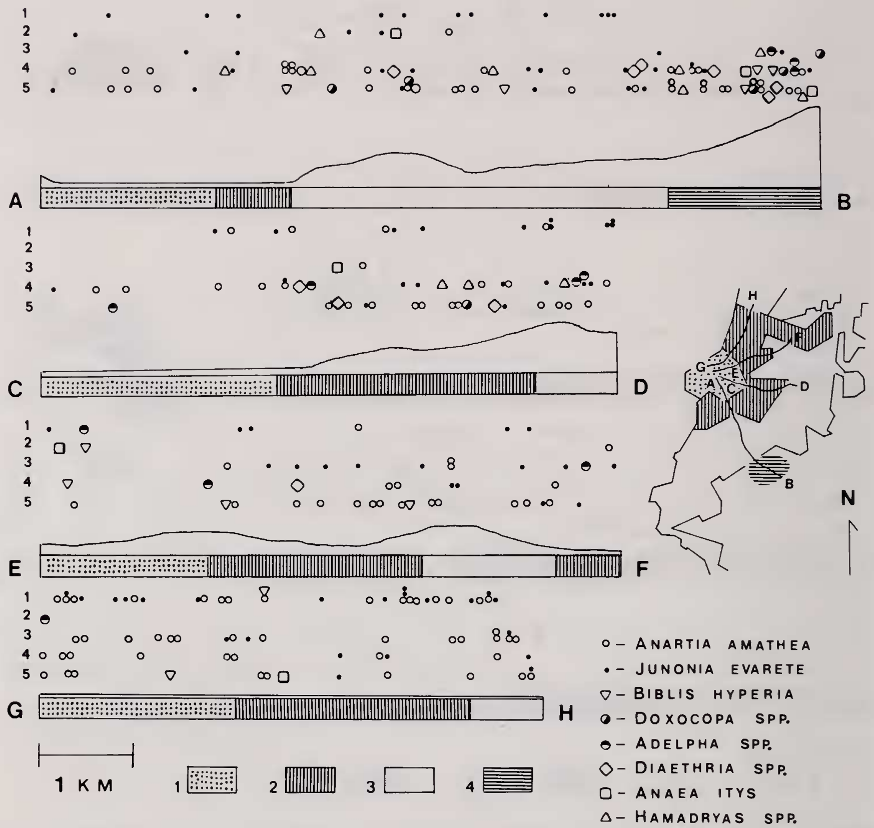


Figure 6. Family Nymphalidae (Miscellanea) — Distribution in the urbanization zones of Porto Alegre. See legend of Figure 3.

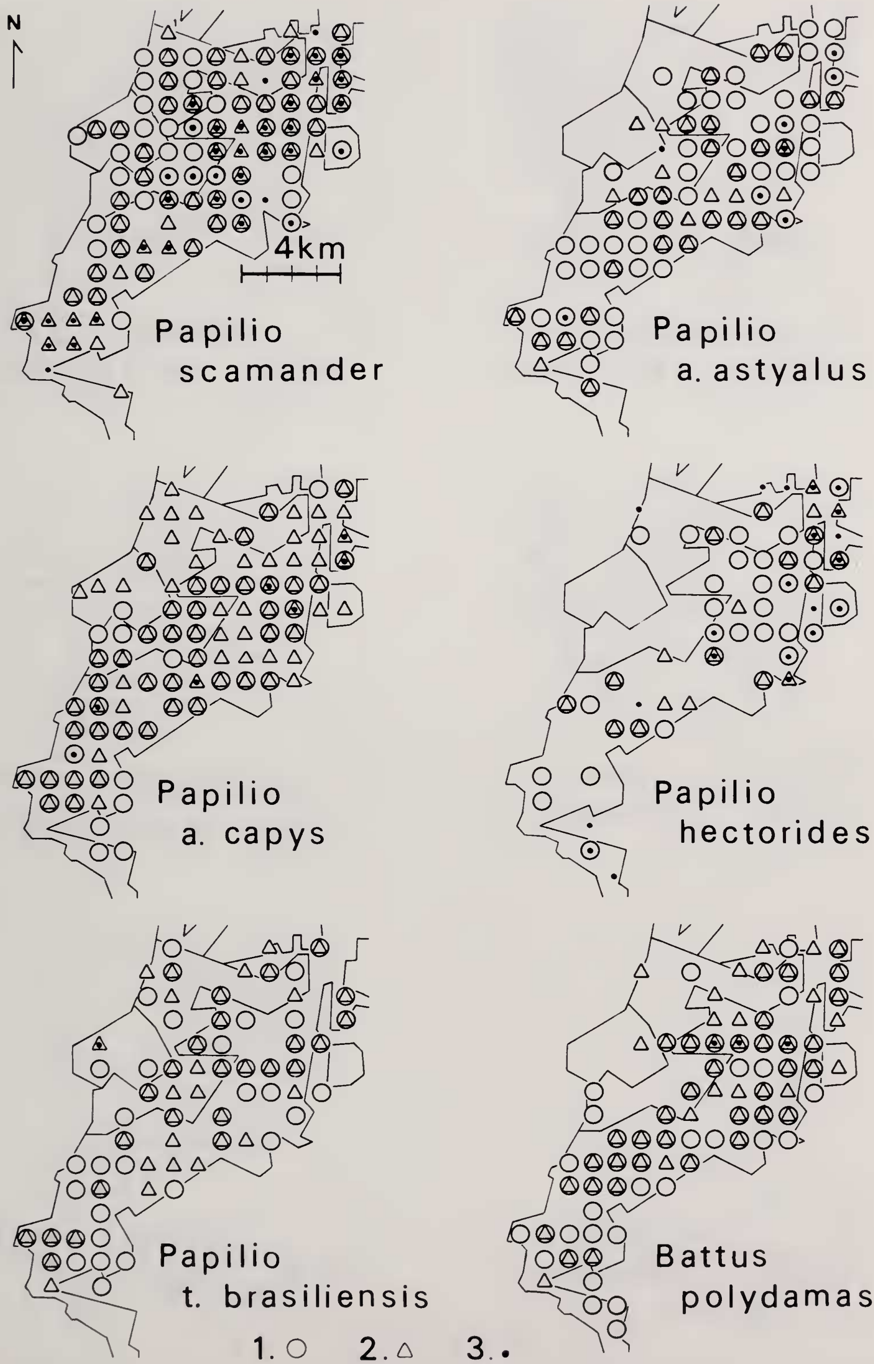
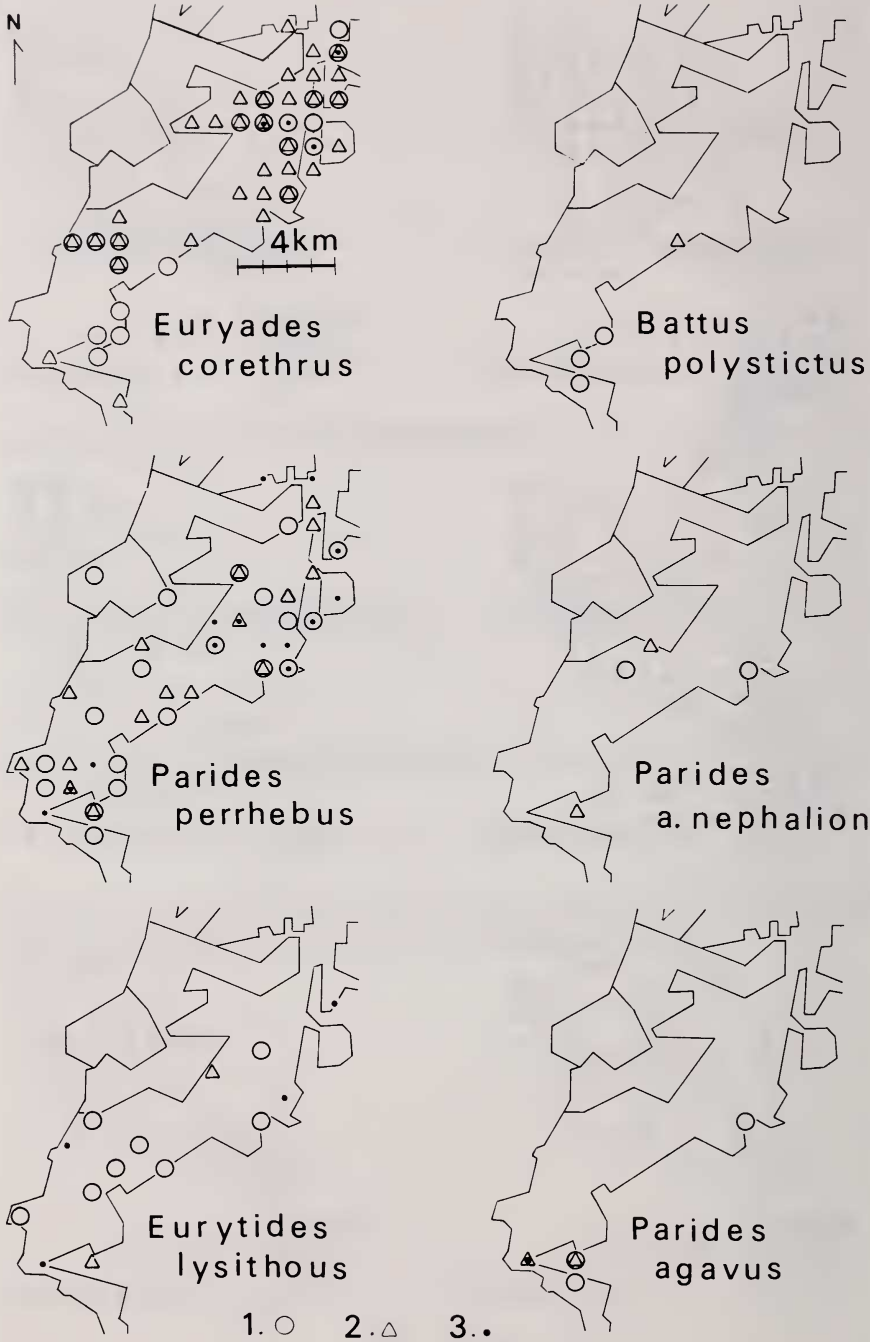


Figure 7. Family Papilionidae — Distribution in the urbanization zones of Porto Alegre. The butterfly fauna of 111 observation points of the urban area was sampled three times, in November-December 1980, March-April 1981 and June-July 1981, respectively 1, 2 and 3.


N
4km
Euryades corethrus
Battus polystictus
Parides perrhebus
Parides a. nephalion
Eurytides lysithous
Parides agavus
1. ○ 2. △ 3. •

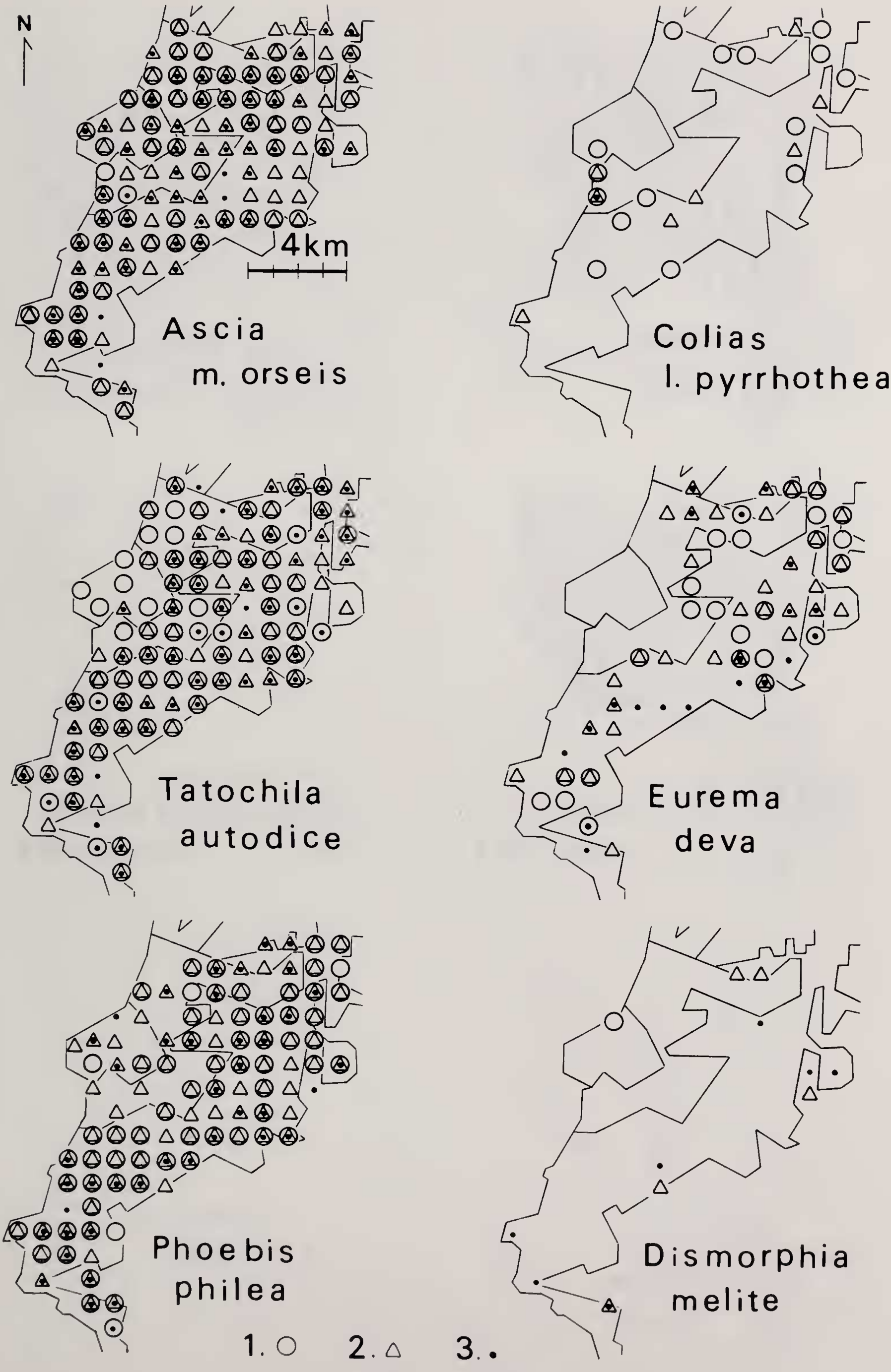


Figure 8. Family Pieridae — Distribution in the urbanization zones of Porto Alegre. See legend of Figure 7.

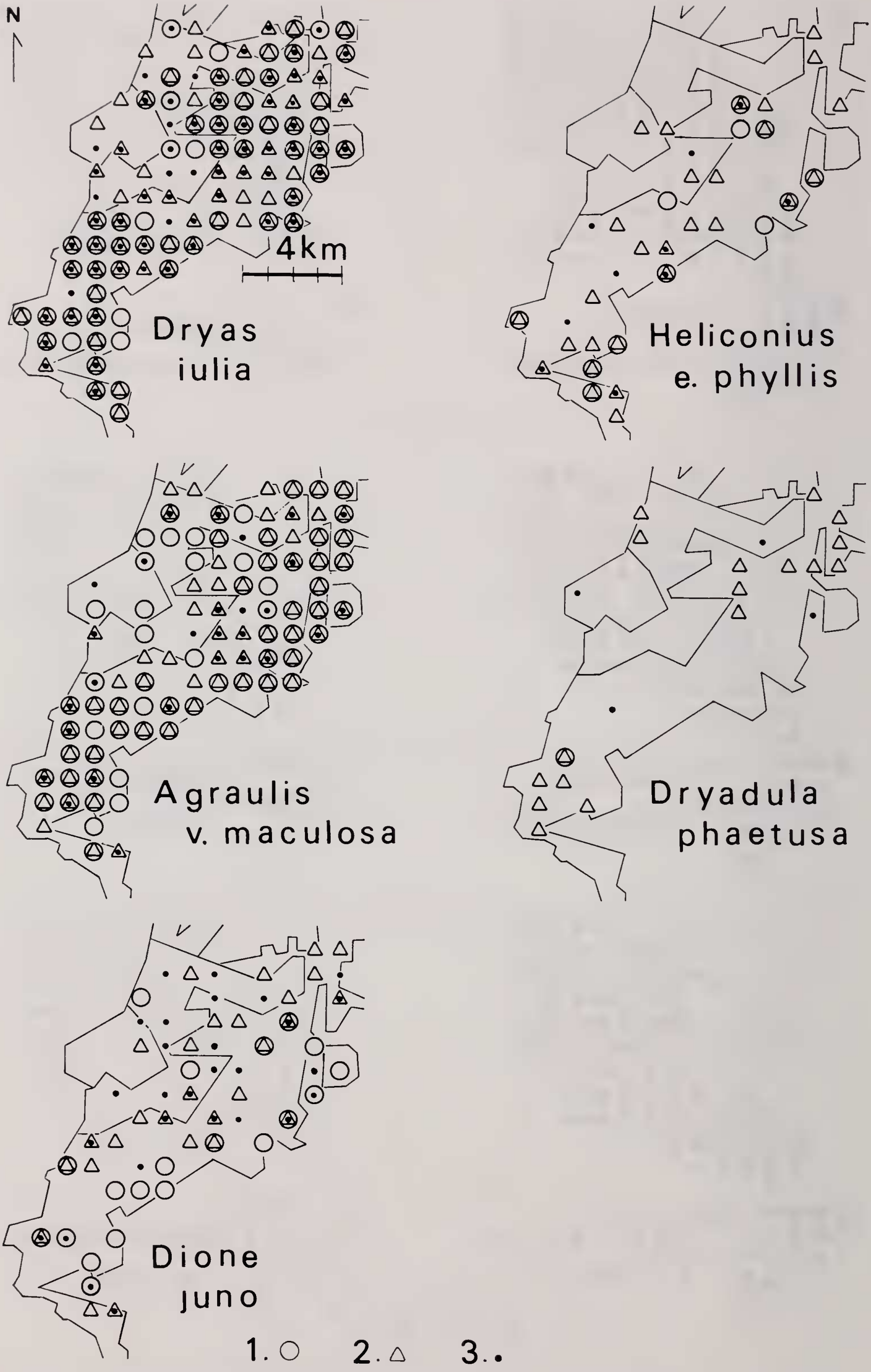


Figure 9. Family Nymphalidae (Heliconiini) — Distribution in the urbanization zones of Porto Alegre. See legend of Figure 7.

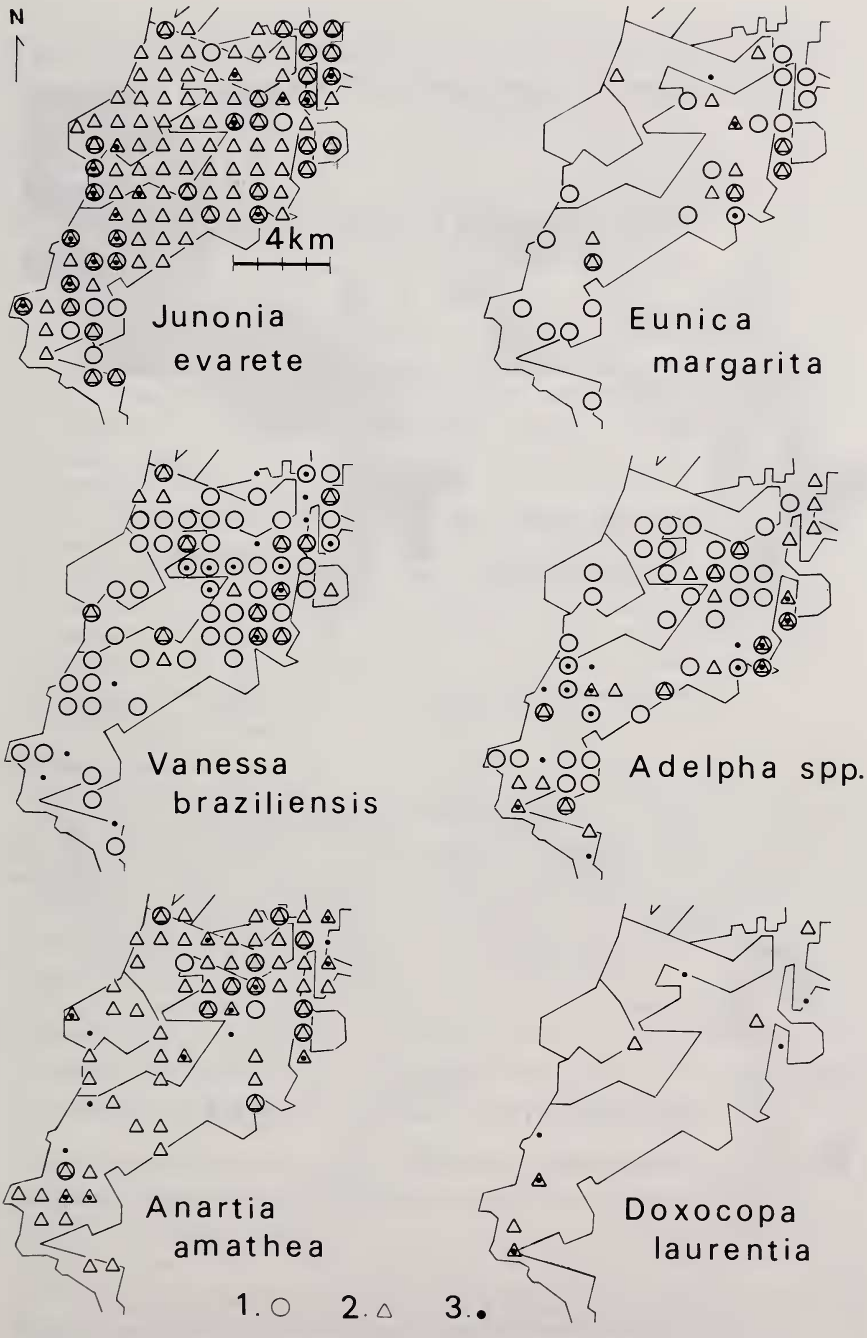


Figure 10. Family Nymphalidae (Nymphalinae) — Distribution in the urbanization zones of Porto Alegre. See legend of Figure 7.

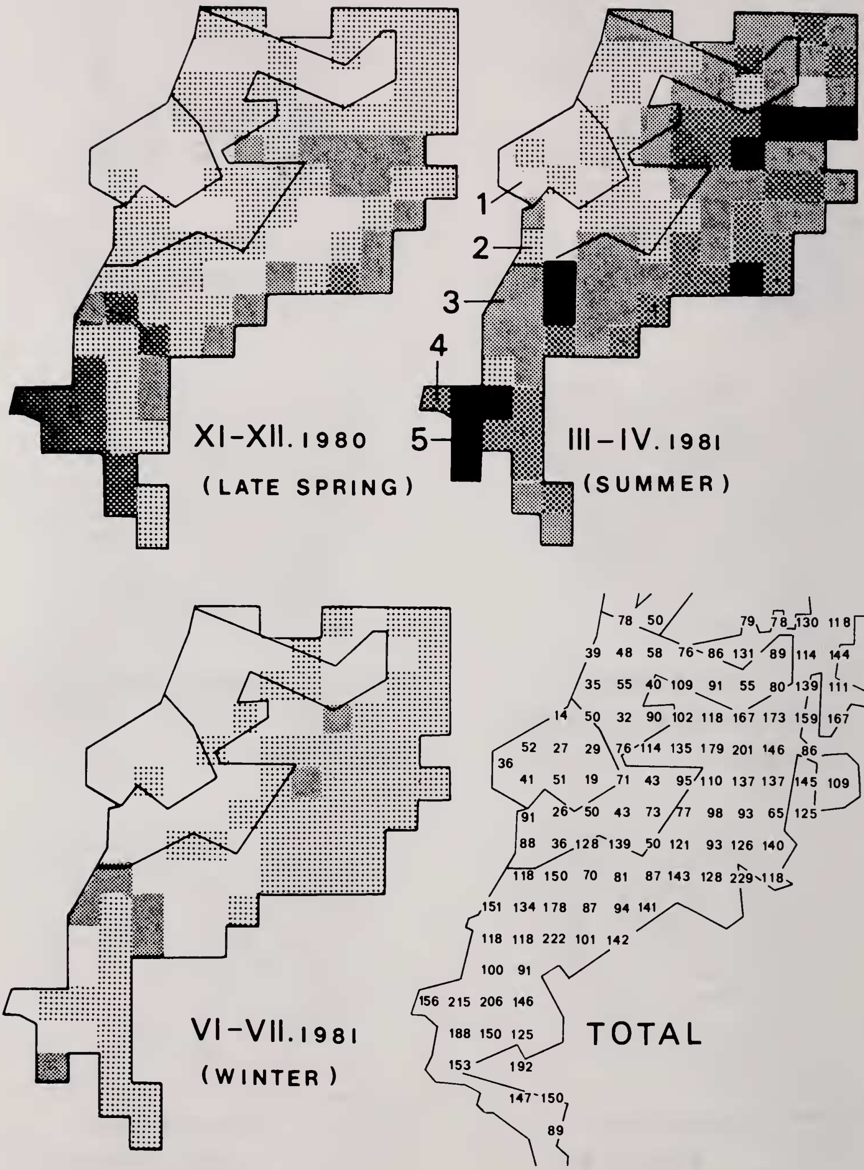


Figure 11. Number of butterflies registered during three samples in 111 observation points of the urban area of Porto Alegre. In each observation point a period of 45 min was spent walking an urban area of 600 m in diameter and recording the butterflies seen. 1, 0–16 individuals; 2, 17–40; 3, 41–70; 4, 71–100; 5, 101–135.